<u>**Attachment B**</u>

<u>**Child Use Areas Ranking System**</u>

(From: Glass, Gregory L. 2002b. Sampling Design for Tacoma Smelter Plume Site; Soil Sampling and Analysis at Child Use Areas in King County and Pierce County, Washington. November.)

In a previous child use areas sampling program on Vashon-Maury Island, it was possible to sample all candidate child use properties where owners agreed to provide access. Given the populations and levels of development in the mainland King County and Pierce County study areas, the results of initial soil surveys (preliminary results for the Pierce County study, still in progress), and a decision to focus on those areas where maximum arsenic concentrations could exceed interim action criteria (see Attachment B), the Design Work Group readily concluded that all candidate child use properties could not be sampled within the available agency resources. Preliminary estimates of the number of candidate child use properties confirmed that resources would be available to sample only a relatively small percentage of all candidate properties.

A method for scoring and ranking candidate child use properties was developed to provide a basis for selecting those child use areas to be sampled. The Design Work Group decided that such a ranking system should be relatively simple to describe, use objective criteria (easily measured) to the extent possible, be able to be applied to a large number of candidate child use properties in a reasonable time with a reasonable level of resource commitments, be well documented, and provide overall ranking and scores related to comparative exposures and risks among properties so that selections would generally be based on a "worst first" principle. Other familiar ranking systems, such as the Washington Ranking Model (WARM) for ranking MTCA sites on a scale of 1 to 5, provided conceptual models for the approach.

The ranked list of child use areas is intended to guide selection of child use areas to be sampled. Other information and considerations may also be used, however, in making final selections (see main text). For example, a geographic allocation scheme may also be used to make sure that some child use areas are included in various parts of the study area. That goal can be met by disaggregating a single overall ranked list into several lists applying to the chosen geographic coverage areas, and then making selections from each list. Similar disaggregated lists can be used if allocations for different types of child use properties are desired. Discussions with local governments and community representatives may also identify priorities for child use area sampling, regardless of rankings, or identify additional child use properties not yet included on the lists (e.g., types of land uses hard to identify from databases, but well known locally, such as vacant lots favored as play areas).

This Attachment will focus on a description of the basic scoring and ranking system. Several examples are provided to illustrate how information on specific

properties is used to develop a score for ranking purposes. Ecology has developed a simple Excel spreadsheet tool that allows information for candidate child use properties to be entered and then automatically calculates a ranking score for each property. Ranked lists of child use properties (single or disaggregated lists) are easily developed using this spreadsheet tool.

The basic structure of the ranking system includes the following elements:

Identification of Factors: a set of characteristics, or factors, that relate to the potential for exposures at a child use property are identified.

Scores: for each identified factor, a measurable variable is identified and a set of "factor scores" is related to the possible values for that variable.

Weights: each factor is assigned a weight reflecting the relative contribution of that factor score to the overall property score.

Total Score: the final score for a candidate child use property is the weighted sum of the individual factor scores. It therefore reflects the contributions of multiple unrelated factors, each of which contributes to the level of "total exposures".

Based on some initial discussions by the Design Work Group on the types of factors to be considered in a ranking system, a detailed preliminary proposal was developed by one participant (N. Peck, Ecology) for further consideration by the Work Group. That preliminary proposal used different ranges of scores for different factors rather than explicit weights for the summation of factor scores. Other participants used information from a number of real and hypothetical child use properties to investigate the performance of this preliminary model. Based on the results, the Design Work Group as a whole decided to modify the proposed system somewhat. Notably, the group chose to use an index scoring system in which the range of scores for every factor was identical, as well as an explicit set of factor weights for creating an overall total score. All factors are now scored in the range of 1 to 5. Most factors are now scored using only three discrete values: 1, 3, or 5 (comparable to low, moderate, or high values); one factor still uses a continuous measure, but it is now "rescaled" to also result in scores within the range of 1 to 5. Default weights of 1.0 are now used as a starting point for all factor scores, with adjustments made to reflect comparative weighting toward final scores (e.g., a weight of 2 would indicate a judgment that one factor was twice as important as others for ranking purposes). The resulting indexed scoring system is relatively simple to understand. The relative contributions of different property characteristics to ranking scores are obvious in this system, simply reflecting the assigned weights.[1] The use of

---

[1]All of the factors contribute to potential exposures in a straightforward manner; total exposures are the product of soil concentrations (adjusted appropriately from undisturbed to developed property conditions), frequencies/durations/intensities of soil contact, and the number of exposed children. Thus, none of the factors is (mathematically) more important than any of the others in estimating exposures. The

indexed scores reduces the importance of small differences in measured characteristics among properties and is appropriate to the quality of information now available to support ranking (e.g., estimated soil arsenic concentrations for unsampled locations).

Information on the scoring approach for factors used in the indexed ranking system is provided below for each of four factors.

Factor 1 (F1) - Population. The first factor considers the number of potentially exposed children at a child use property. Priority is given to those locations where a larger number of young children may be exposed to contaminated soils. The importance of age was considered by the Design Work Group. Incidental soil ingestion through mouthing behaviors, as well as purposeful soil ingestion (pica), are believed to be more characteristic of children at or below the age of 6 years. The urinary arsenic monitoring results from the University of Washington Exposure Pathways Study in communities near the former Tacoma Smelter were reviewed for information on exposures of somewhat older children, but relatively few children 7 or older were monitored and the results were therefore inconclusive with respect to the levels of exposure of these older children. The Work Group decided to use estimates of the population of children 6 years old or younger as a measure of the number of potentially exposed children for ranking purposes. That age range has often been used to focus on the most highly exposed group of children. It should be emphasized that this does not reflect a finding that soil exposures stop past the age of 6 years; on the contrary, some incidental exposures to soils, at reduced levels, may occur at ages through adulthood.

Indexed scores for the population factor (ages 0 to 6 years) were assigned as follows:

1 to 10 children	score = 1
10 to 50 children	score = 3
more than 50 children	score = 5

The population factor was assigned a factor weight of 1.0.

Factor 2 (F2) - Soil Arsenic Concentration. The second factor considers the level of soil arsenic to which children may be exposed. Priority was given to child use

---

weights instead reflect judgments about the best approach to selecting the small subset of candidate child use areas for sampling under substantial resource constraints. That is, they reflect judgments about how to balance what are roughly numerically equal "total exposures" where the number of children is small and the concentrations are high versus the number of children is large and the concentrations are lower (and other similar comparisons).

properties where greater levels of soil arsenic could occur. At a regional scale, the initial soil surveys demonstrate convincingly that levels of soil contamination reflect property locations with respect to the smelter; gradients with distance and corresponding to relative wind frequencies (i.e., direction) are shown by the data, as expected. However, substantial local variability in soil arsenic concentrations occurs, so that meaningful predictions of the concentrations at specific unsampled properties are not possible. The regional-scale patterns of soil contamination are therefore used to provide an estimate of the maximum likely arsenic concentrations in soils at child use properties, based on their locations. The equation for the appropriate bounding curve for maximum arsenic concentration versus distance, by wind sector, is used to calculate the maximum value used for ranking purposes. In many cases these bounding curves were estimated from data for relatively undisturbed, forested locations, and therefore may be conservative when applied to developed properties (see the discussion under Factor 3, below).

Indexed scores for the soil arsenic concentration factor were assigned as follows:

less than 150 ppm	score = 1
150 to 250 ppm	score = 3
greater than 250 ppm	score = 5

The soil concentration factor was assigned a factor weight of 1.5, reflecting the judgment of the Work Group that the selection of child use areas for sampling should be biased (more than proportionally among factors) toward the areas of greatest impact from smelter emissions.

Wind directions surrounding the smelter were divided into 16 vectors (A-P), each covering 22.5 degrees. Vectors in the Pierce County CUA Study are D, E, H, I, J, K, L, and M, which roughly correspond to compass directions ENE through SSW (refer to Figure 1).

Factor 3 (F3) - Property Development. The third factor considers the period since property development, or major redevelopment, for deposited smelter contaminants to accumulate. Priority is given to properties where a longer period for contaminant accumulation has occurred. Property development actions are considered likely to reduce, and can even eliminate, the near-surface soil contamination that accumulates in undisturbed soils from deposition of airborne smelter emissions. While the time since property development actions can be considered only an imperfect measure of this effect - the degree to which undisturbed soil contaminant concentrations are affected depends on the specific development actions disturbing soils - it is nonetheless considered a useful indicator. Ecology's study of University Place residential properties showed the age of residence was to be related to soil arsenic concentrations.

Smelter emissions were ongoing throughout the period of smelter operations (varying somewhat year-to-year as a result of copper production levels, labor strikes,

pollution control equipment, and other variables). Thus, all else being equal, the period since major development actions should be an indicator for the degree to which soil contaminant levels approach those in nearby undisturbed soils. A property with major development activities after smelter shutdown in 1986 may not have all accumulated soil contamination eliminated, but it would have had no opportunity for further accumulations post-development. It is reasonable to characterize such a property as less contaminated, on average, than a similarly located property which has not had development activities for many decades, and which therefore probably reflects continued accumulation from contaminant deposition. The third factor can thus be thought of as addressing the possible degree of conservatism in the maximum arsenic concentration estimated from the bounding curve for undisturbed soils.

The Work Group determined that this factor should be scored on a continuous scale within the range of index scores, 1 to 5, based on the fraction of the smelter's total operating period (1890 to 1986, or 96 years) represented by the period since property development. Thus, the factor score is calculated by

$$\text{score} \;=\; 1 \;+\; ([1986 - \text{Year}]/[1986 - 1890])4$$

where "Year" is the year of property development, or major redevelopment, constrained to be between 1986 and 1890; that is, any development year after 1986 is assigned 1986 and any development year before 1890 is assigned 1890, so that the fraction in the equation is always between 0 and 1.

The property development factor was assigned a weight of 1.0.

Factor 4 (F4) - Soil Contact Frequency and Duration. The fourth factor considers the likely frequency (e.g., days per year) and duration (e.g., hours per day) of soil contact that could result in contaminant exposures. Priority was given to child use areas where a greater amount of soil contact may occur. Various types of child use areas - schools versus camps, for example - appear to have characteristic values for exposure frequencies and durations. For this factor, the Work Group adopted default assumptions (as originally developed in N. Peck's preliminary proposal for a ranking system) for different types of child use areas as a basis for assigning index scores. If property-specific information is available and well-supported that differs from the default assumptions, that information may be used to modify the default assigned score for the soil contact factor.

Indexed scores for the soil contact factor were assigned as follows:

camps	score = 1
parks, playfields, vacant lots,	score = 2

gardens

schools,   score = 3
preschools,
daycare centers,
local playgrounds at housing complexes

with other types of child use areas, if any, assigned scores based on similarity to the identified property uses above.

The soil contact factor was assigned a weight of 1.0.

The overall ranking scores are calculated as the weighted sums of the four factor scores. With the assigned weight of 1.5 for the soil concentration factor (F2), and a range of 1 to 5 for raw scores for each factor, the overall range of total scores is 4.5 to 22.5. Several examples below illustrate how ranking scores for child use properties are developed. For these examples, the equations for the bounding curves derived for King County wind sectors (see Attachment B) are used to calculate factor scores for soil arsenic concentrations.

Example 1. A preschool, located in the northeast wind sector at a distance of 11.5 miles from the smelter, has 32 children ages 0 to 6 years in attendance. It was built in 1955.

F(1):   a population of 32 children results in a score of 3 (10 to 50 children).

F(2):   the bounding curve equation of max arsenic = $1{,}500 \times 10^{-0.063 \, \text{Distance}}$ results in a value of 283 ppm at 11.5 miles. The factor score is 5 (greater than 250 ppm).

F(3):   built in 1955, the post-development period is 31 years out of a total smelter operating period of 96 years. The factor score is therefore (1 + [31/96]4), or 2.29.

F(4):   a preschool is assigned a factor score of 5 based on assumed exposure frequency and duration values.

Total score: 3 + (1.5)5 + 2.29 + 5 = 17.79

Example 2. A park, located in the north-northeast wind sector at a distance of 13.5 miles from the smelter, is used by an estimated 80 young children. It was developed in 1928.

F(1):   a population of 80 children results in a score of 5 (more than 50 children).

F(2): the bounding curve equation of max arsenic = 700 x 10 $^{-0.045\ Distance}$ results in a value of 173 ppm at 13.5 miles. The factor score is 3 (150 to 250 ppm).

F(3): built in 1928, the post-development period is 58 years out of a total smelter operating period of 96 years. The factor score is therefore (1 + [58/96]4), or 3.42.

F(4): a park is assigned a factor score of 3 based on assumed exposure frequency and duration values.

Total score: 5 + (1.5)3 + 3.42 + 3 = 15.92

Example 3. A daycare center, located in the east-northeast wind sector at a distance of 14 miles from the smelter, has 9 enrolled children younger than 6 years old. It is located in a private residence built in 1977.

F(1): a population of 9 children results in a score of 1 (1 to 10 children).

F(2): the bounding curve equation of max arsenic = 1,125 x 10 $^{-0.071\ Distance}$ results in a value of 114 ppm at 14 miles. The factor score is 1 (less than 150 ppm).

F(3): built in 1977, the post-development period is 9 years out of a total smelter operating period of 96 years. The factor score is therefore (1 + [9/96]4), or 1.38.

F(4): a daycare center is assigned a factor score of 5 based on assumed exposure frequency and duration values.

Total score: 1 + (1.5)1 + 1.38 + 5 = 8.88

Example 4. An elementary school, located in the north-northeast wind sector at a distance of 16.5 miles from the smelter, has a total enrollment of 318 children. The estimated number of children aged 0 to 6 years is assumed to represent one-third of total enrollment (kindergarten plus first grade, out of K-5 classes), or 106 children. The school was built in 1962.

F(1): a population of 106 children results in a score of 5 (more than 50 children).

F(2): the bounding curve equation of max arsenic = 700 x 10 $^{-0.045\ Distance}$ results in a value of 127 ppm at 16.5 miles. The factor score is 1 (less than 150 ppm).

F(3): built in 1962, the post-development period is 24 years out of a total smelter operating period of 96 years. The factor score is therefore $(1 + [24/96]4)$, or 2.00.

F(4): an elementary school is assigned a factor score of 5 based on assumed exposure frequency and duration values.

Total score: $5 + (1.5)1 + 2.00 + 5 \ = \ 13.50$